The development of an ethocel automobile touch-up lacquer and a suitable sanding surfacer : II. a study of the physiological effect of color using the Munsell Color Notation.

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PART I

THE DEVELOPMENT OF AN ETHOCEL AUTOMOBILE TOUCH-UP LACQUER AND A SUITABLE SANDING SURFACER

PART II

A STUDY OF THE PHYSIOLOGICAL EFFECT OF COLOR USING THE MUNSELL COLOR NOTATION

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PART I

THE DEVELOPMENT OF AN ETHOCEL AUTOMOBILE TOUCH-UP LACQUER AND A SUITABLE SANDING SURFACER

ABSTRACT

The object of this research is to develop an ethocel automobile touch-up lacquer and a satisfactory ethocel sanding surfacer. The research was conducted by selecting a number of commercially available resins and plasticizers and varying the per cents resin, plasticizer, ethocel and solvent so as to obtain the desired qualities in the finished coating. In 1942, Ernst, Graef and the author did some research on the problem and developed a surfacer and an automobile lacquer No. 62 (Table I) that exhibited good properties but that was too high in price. The present research is a continuation of this earlier study.

Pigmentation of the clear lacquers used in this study presented a "grinding problem." Another difficulty was encountered in obtaining adhesion between the lacquer film and a steel panel.

Both the grey sanding surfacer to be used in conjunction with the black ethocel automobile touch-up lacquer and the lacquer itself were formulated according to the same procedure.

The research leading to the development of a satisfactory ethocel automobile touch-up lacquer necessitated a very thorough investigation of many lacquer raw materials.

The use of a desirable solvent ratio was arrived at after encountering much difficulty in spraying; but by varying proportions of toluol, ethanol and butanol, this problem was completely solved.

The same difficulty was encountered in the lacquer formulation as was encountered in the surfacer formulation with respect to the solvent ratio.

There were two sufacer pigment combinations used throughout this research. The first combination was that of Surfacer Formulation No. 62 (Table I); and the second combination, that of Surfacer Formulation No. 179 (Table II).

The grey sanding surfacer shows great possibility in the commercial field because it exhibits properties that are second to no surfacer on the market today. An ethocel automobile touch-up lacquer will not reach the market with the present resins that are available, and in the future it is recommended that no further work be done on a touch-up lacquer until more suitable resins are developed.

PART II

A STUDY OF THE PHYSIOLOGICAL EFFECT OF COLOR USING THE MUNSELL COLOR NOTATION

ABSTRACT

The purpose of this research was to determine the change in shade that was preferred by a customer if the favorite color were to change because of age. This change is one that has been noticed as a protective coating ages and changes from one shade of a color to an entirely different shade. Knowing the preference of a customer, this change may be made pleasing or displeasing depending upon the formulation of the basic color. This study utilized the Munsell Color Notation (13) that is described in the thesis. The observer's hue, value and chroma preferences were determined by a series of tests fully described in the section on "Test Procedure."

It was concluded that all observers tend to choose a color that will look best on some particular object. Almost everyone claiming color-blindness could distinguish a difference in any two colors, therefore results of tests were not materially changed. From the findings of one or two colors it is impossible to forecast the results for a third color.

In all cases the bluer hue was preferred, but to a greater extent by women, especially in the case of red and green.

In all cases women prefer their colors to be brighter than do men. Men prefer dark reds, medium greens and light yellow reds.

As for chroma, men like greens to be quite grey, but yellow reds to be well saturated. Women are just the opposite. Both men and women, however, want reds of strong chroma.

PART I

THE DEVELOPMENT OF AN ETHOCEL AUTOMOBILE TOUCH-UP LACQUER AND A SUITABLE SANDING SURFACER

INTRODUCTION

The object of this research is to develop an ethocel automobile touch-up lacquer and a satisfactory ethocel sanding surfacer.

Ethocel is a cellulose ester resulting from the interaction of ethyl chloride and alkali cellulose. It is manufactured by the Dow Chemical Company of Midland, Michigan. This cellulose derivative yields a greater volume of film-forming solids per unit weight than any other commercial derivative, adding toughness to a lacquer as well as an unusual degree of flexibility. These are very favorable attributes when a material is being selected to be a constituent of a lacquer type protective coating.

This research was conducted by selecting a number of commercially available resins and plasticizers, and varying the percents of resin, plasticizer, ethocel and solvent so as to obtain the desired qualities in the finished coating.

HISTORICAL

The first description of ethocel and methods for its manufacture and preparation probably appeared in 1905 in Monatshefte fur Chemie by Suida (1). There were many patents obtained on the preparation of the ether, some being those of Dreyfus (2) and Leuchs (3). The high cost of manufacture prevented the widespread industrial use of this material until recent years. In 1936 ethocel ceased to be an import and its manufacture was begun in this country. It is now on the market at a cost that makes it available for industrial use.

Ethocel is manufactured according to the classical methods for the manufacture of the cellulose ethers. Cellulose is converted into alkali cellulose by treatment with strong aqueous solutions of sodium hydroxide. This alkali cellulose is alkylated with such reagents as ethyl chloride or sulfate. To avoid degeneration of the cellulose and of the alkylating agent, the alkylation is carried out with very careful temperature control. When the reaction is completed, the reagent and the by-products are separated by washing and by distillation. By repeated washing with water, the purification of ethocel is finally completed.

Ethocel may vary in properties according to the degree of esterification that has taken place. The particular type of ethocel that was employed in this study was "Standard Ethocel" having a viscosity of 10 to 50 centipoise. This material has an ethoxy content of 48.5 to 49.5 per cent.

Ethocel is a white solid that in its powdered form resembles crystalline sodium chloride. It resembles nitro cellulose in its compatibility with other film-forming ingredients and it has the widest solubility of any commercially available film-forming material. It also exhibits a greater flexibility and toughness than the other derivatives of cellulose and it retains its flexibility at temperatures as low as -40° C.

In 1942, Ernst, Graef and the author did some research on this problem and developed a surfacer and an automobile lacquer No. 62 (Table I) that exhibited suitable properties, but the price was too costly. The present research is a continuation of the above work.

THEORETICAL

Depending upon the purpose for which a lacquer is to be used, the formulation may vary considerably. For example, an automobile lacquer need not be as viscous and as quick-drying as a pencil lacquer. The film cast by an automobile lacquer must have a greater hardness, adhesion and durability than any of the other lacquers in production today.

A lacquer may be divided into two distinct components, each of which has a very pronounced effect upon the final properties of the lacquer.

The non-volatile portion of the lacquer contains the film-forming constituents, and it is by varying these materials, viz., resin, plasticizer and pigment, that different properties are imparted to the lacquer film. The resin gives adhesion, hardness and gloss to the film; thus, the type or the proportion of resin may impart a variety of properties to the film. Three considerations that determine the use of a particular lacquer are: (1) fulfillment of the required physical properties for the film (2) compatibility with the other constituents of the lacquer (3) suitability of price for sale on competitive markets.

The plasticizer, either chemical or resin type, is used to give the film the required flexibility. Plasticizers are materials such as tricresyl phosphate and dioctylphthalate. In some cases, the resin used is a plasticizer resin and the desired flexibility is obtained without the use of a plasticizer as such.

Pigments are used in lacquer for their decorative effect and for their hiding power. It is very seldom that only one pigment will be used in a lacquer; usually two or more are required to achieve the desired color and hiding power. Certain effects produced on the film by the pigment are: the filling of pits, the increase of adhesion and the improvement of corrosion resistance.

The volatile portion of a lacquer consists of various combinations of volatile solvents. Three conditions that these solvents must fulfill are: (1) compatibility with all constituents of the lacquer (2) evaporation that will leave a tack free film in the required time (3) evaporation at a rate that will not result in any undesirable effects upon the film. If the solvents are too volatile, a condensation of moisture will occur, giving the film a blushed effect. If the solvents evaporate too slowly, there will be a tendency for the film to sag before it obtains the initial set. Strict adherence to the above-mentioned conditions will result in a satisfactory film.

Pigmentation of the clear lacquer used in this study presented a "grinding" problem. An effort was first made to pigment the clear lacquer by the use of a ball mill, but this method did not prove satisfactory. In an effort to solve this problem, lacquer chips were next used; and when the proper results were not obtained, a dispersion of carbon black, ethocel, alcohol and toluol was used. The latter dispersion was manufactured by the R.B.H. Co. and was designated as RBH Dispersion No. 9002. The composition of RBH Dispersion No. 9002, which worked very satisfactorily, may be found in Table 1.

The following section reveals the conditions necessary for adhesion between the lacquer film and a steel panel, which for this problem presented a special difficulty.

The study of the conditions that bring about adhesion of a protective coating to a metal surface with relation to its importance in the formulation of a satisfactory coating is one that has received little consideration. The mechanics of adhesion are very clearly set forth, but in only one recorded case (4,5,6,7,8,9,10) have definite suggestions been made to improve adhesion. These suggestions were mentioned in (4) and are explained as follows.

A. Interlocking Phenomena

(1) These phenomena exist when the surface of the metal has many minute irregularities. Such a condition may be brought about by sand-blasting, etching with acid, or by the use of any other method that will produce irregularities in the surface. The film is able to get down into each of these small recesses and by so doing, gain better adhesion to the metallic surface.

(2) A film of oxide, carbonate, or phosphate is applied to the surface of the metal and the lacquer film adheres to it because of the irregular surface that is produced.

B. Chemical Surface Attack by a Constituent of the Film

Adhesion is produced by a constituent of the coating that combines chemically with the metallic surface. There is little or no evidence of the above chemical attack taking place when an organic coating is applied to a metallic surface.

C. Adsorption Force

A protective coating adhering to a metallic surface is the most important and is the one that deserves most consideration. Some difficulty has been encountered in explaining the different theories of adsorption and the complete explanation lies beyond the scope of this thesis. The two methods of adhesion by this method are as follows.

(1) A material that is known to be highly absorbed when brought into contact with the metallic surface is included in the formulation of the coating. When the coating dries, one end of the molecule is embedded in the metallic surface and the other end is embedded in the film body, thus giving the coating proper adhesion.

(2) When a chemical group is found that is absorbed readily by the metallic surface, this group is chemically reacted with suitable coating materials. When the coating is applied to the surface, the group to be absorbed is a part of the coating; so it is absorbed as before, imparting to the coating sufficient adhesion.

A research of literature on this subject yielded the following conclusions. It has been found that carboxyl groups on alkyd resin molecules are very advantageous when good adhesion is required. The addition of a non-drying phthalate resin tends to perform two duties, namely, plasticizing the film and introducing polar groups that may aid in the adsorption of the material to the metal surface. The film may possess good adhesion if the shrinkage of the lacquer is not too great on drying. This shrinkage tends to destroy the adhesion of the film to the surface because of the tremendous forces brought in to play.

Vinyl acetate and other vinyl compounds were mentioned as an aid in making ethyl cellulose glue and other binding compounds. It is believed, therefore, that vinyl resins will be of assistance in increasing the adhesion of ethyl cellulose lacquers. For example, polyvinylchloride could be used in the granular form and when taken up with methyl ketone, it could be incorporated into a lacquer.

It is of primary importance that the surface to be coated be thoroughly cleaned. This cleansing is best accomplished by washing the surface with alcohol or acetone, then by sanding with No. 0 sandpaper and washing again with a solvent.

EXPERIMENTAL

The grey sanding surfacer to be used in conjunction with the black ethocel automobile touch-up lacquer was formulated according to the same procedure that was followed in the formulation of the lacquer.

There were two surface pigment combinations used throughout this research. The first combination was that of Surfacer Formulation No. 62(Table I), and the second combination, that of Surfacer Formulation No. 179 (Table II). The reason for the use of the two combinations was that all possibilities of using the No. 62 combination in a successful formulation had been exhausted in previous work (11, 12) and No. 179 combination was chosen in an effert to secure a workable pigment system. No. 179 pigment system consisted of Titanox B, Barytes and Soapstone.

During this research, the majority of commercial resins was investigated as possible constituents for the surfacer with very little success until the oil-modified alkyd resin RR-1071 manufactured by the Reliance Varnish Company of Louisville, Kentucky was used. RR-1071 used in the proportions shown in Surfacer Formulation No. 179 (Table II) imparted to the film all properties desirable in a good sanding surfacer.

The possibilities of using other viscosity ethocel in place of 20 cps. met with little success. The higher viscosity ethocel made the film more brittle, thus being of no value. The reason for this phenomenon is beyond the scope of this research.

The use of a desirable solvent ratio was arrived at after encountering much difficulty in spraying; but by varying the proportions of toluol, ethocel and butanal, this problem was completely solved.

The research leading to the development of a satisfactory ethocel automobile touch-up lacquer necessitated a very thorough investigation of many lacquer raw materials.

Pigmentation of the lacquer was first tried by dispersing the carbon black with the use of a ball mill. It was not possible to effect this dispersion to a satisfactory degree and as a result of the lack of dispersion, the gloss of the finished film was considerably reduced.

The use of lacquer chips, pigment mixed with lacquer solvent and ethocel and dispersed on a roller mill, was then determined by incorporating them into several formulations. This method of pigmentation was not successful because there was still a lack of gloss. It is safe to assume that the lacquer chips were not well dispersed. The problem of dispersion was finally solved by using a commercial dispersion of 15% Carbon Black, 15% 10 Cps. Standard Ethocel, 14% Ethanol and 56% Toluol, manufactured by R. B. H. Co. of Newark, N. J. and referred to as R.B.H. Dispersion No. 9002.

Many commercial resins and plasticizer combinations were used, such as Superbeckacite 3000, Durez 570, Durez 550, Beckacite 1111, Aroplaz 930, Tricresyl phosphate, castor oil, di-octyl phthalate, etc. The resin and plasticiser modified alkyd resin RR-1071 manufactured by the Reliance Varnish Company. RR-1071 imparted to the film a desirable hardness, adhesion and flexibility.

Ethocel, 20 cps, standard ethoxy content, was the only Ethocel that gave a good hard film. Standard Ethocel and medium ethocel with viscosities ranging from 7 cps to 50 cps were investigated; but no satisfactory results were obtained.

The same difficulty was encountered in the lacquer formulation as was encountered in the surfacer formulation with respect to the solvent ratio. The time required for the initial set of the film introduced the solvent problem. If the time required for the initial set was too short the film would sag; and if it was too short, the lacquer would hit the panel dry and produce a very grainy orange-peel surface. The solvents have to be so regulated by the addition of fast- or slow-exaporating solvents that the lacquer will flow out into a smooth film when applied to the surface to be lacquered.

Cold-rolled steel panels were used to simulate the body of an automobile. These panels were prepared by sanding with No. 0 sandpaper in the presence of a lacquer solvent in order to completely degrease the surface.

One coat of surfacer was sprayed on the panel and was allowed to age for twenty-four hours at which time it was water sanded with No. 0 sandpaper to give a perfectly smooth surface. One coat of lacquer was then applied and allowed to age for two weeks at which time the lacquer was put into an oven at 70° C for one hour in order to completely effect its curing.

The panels were submitted to the "Bend Test" for flexibility, hardness tests, and knife-blade tests.

The bend test consisted of bending the panel through 180° over a 3/8 inch steel mandrel and noting the conditions of the film.

The pencil hardness test consisted of scratching the dry film with pencils of hardness ranging from H to 7H. The harder the pencil required to scratch the film, the harder the film; e.g., a film that required a 5H pencil to scratch it was harder than a film that required a 2H pencil to scratch it. The hardness of the pencil scratching the surface designated the hardness of the film. The angle of the pencil with the panel was 45° and the pressure on the pencil was that usually used in writing.

The knife-blade adhesion test was performed by scarring the surface of the film with a knife blade, making a number of 1mm squares. The relative ease with which the squares were removed was the index of adhesion.

SURFACER FORMULATION NO. 62

Table I

Lithopone	11.62 %	
China Clay	4.13%	
Celite CN-110	3.34%	
Asbestine	4.13%	
Carbon Black	4.58%)	30.3% RHB Dispersion
Ethocel	4.58%)	No. 9002
Ethanol	4.24%)	
Toluol	16.90%)	
Super Beckacite 3000	8.65%	
Aroplaz 930	4.32%	
Ethanol	4.83%	
Toluol	24.21%	

PEBBLE MILL GRIND

10 cps. Ethocel std. ethoxy	4.47%
	100.00%

TOP COAT FORMULATION NO. 62

Carbon Black	0.89%)	
10 cps. Ethocel std.	0.89%)	5.95% RHB Dispersion
Ethanol	0.83%)	No. 9002
Toluol	3.33%)	
10 cps. std. Ethocel	10.60%	
Aroplaz 930	5.70%	
Super Beckacite 3000	11.50%	
Ethanol	12.20%	
Toluol	54.06%	
	100.00%	

SURFACER FORMULATION NO. 179

Table II

Solid			Batch	
50	grams	Titanox B	50	grams
30	grams	Barytes	30	grams
107	grams	Soapstone	107	grams
83	grams	(RR-1071 Resin (50% xylol	166	grams
		Toluol	275	grams
		Ethanol	75½	grams
		Butanol	10	grams
39	grams	50 cps. Ethocel std.	39	grams
309	grams		752½	grams

Disperse forty-eight hours in a steel ball mill.

Reduce (1 part 179
(1 part Dow Solvent #6

180 GREY SANDING SURFACER

Table II (continued)

This has the same formulation as 179 with the exception that 10 cps. Standard Ethocel was used instead of 50 cps. Standard Ethocel.

SURFACER FORMULATION NO. 180 A

Solid		Batch
50 grams	Titanox B	50 grams
30 grams	Barytes	30 grams
107 grams	Soapstone	107 grams
54.4 grams	Super Beckacite 3000	54.4 grams
27.4 grams	Aroplaz 930	27.7 grams
	Toluol	275 grams
	Ethanol	78 grams
	Buthanol	10 grams
39 grams	10 cps. Ethocel, std.	38 grams
307.8 grams		670.1 grams

Disperse forty-eight hours in a steel ball mill.

Reduce (1 part 179
(1 part Dow Solvent #6

SURFACER FORMULATION NO. 180 B

Table II (continued)

Solids			Batch	
50	grams	Titanox B	50	grams
30	grams	Barytes	30	grams
107	grams	Soapstone	107	grams
64.4	grams	Super Beckacite 3000	64.4	grams
17.7	grams	Aroplaz 930	17.6	grams
		Toluol	275	grams
		Ethanol	77	grams
		Butanol	10	grams
39	grams	10 cps. Ethocel std.	39	grams
308.1	grams		670.0	grams

Disperse forty-eight hours in a steel ball mill.

Reduce {1 part 179
{1 part Dow Solvent #6

SURFACER FORMULATION NO. 180 C

Solids			Batch	
50	grams	Titanox B	50	grams
30	grams	Barytes	30	grams
107	grams	Soapstone	107	grams
74.4	grams	Super Beckacite 3000	74.4	grams
7.7	grams	Aroplaz 930	7.7	grams
		Toluol	275	grams
		Ethanol	78	grams
		Butanol	12	grams
39	grams	Ethocel 10 cps. std.	39	grams
308.1	grams		673.1	grams

Disperse forty-eight hours in a steel ball mill.

Reduce {1 part 179
{1 part Dow Solvent #6

SURFACER FORMULATION NO. 180 D

Table II (continued)

Solid			Batch	
50	grams	Titanox B	50	grams
30	grams	Barytes	30	grams
107	grams	Soapstone	107	grams
72	grams	Durez 570	72	grams
12	grams	Aroplaz 930	12	grams
		Toluol	275	grams
		Ethanol	78	grams
		Buthanol	10	grams
39	grams	Ethocel 10 cps. std.	39	grams
310.0	grams		673.0	grams

Disperse forty-eight hours in a steel ball mill.

Reduce {1 part 179
1 part Dow Solvent #6

SURFACER FORMULATION NO. 180 E

Solid			Batch	
50	grams	Titanox B	50	grams
30	grams	Barytes	30	grams
107	grams	Soapstone	107	grams
72	grams	Durez 550	72	grams
12	grams	Aroplaz 930	12	grams
		Toluol	275	grams
		Ethanol	78½	grams
		Butanol	10	grams
39	grams	Ethocel 10 cps. std.	39	grams
310	grams		673.5	grams

Disperse forty-eight hours in a steel ball mill.

Reduce {1 part No. 179
1 part Dow Solvent No. 6

SURFACER FORMULATION NO. 181

This formulation is the same as 179 except that 20 cps. Medium Ethocel are used.

TABLE III

TOP COAT FORMULATIONS

	175	176	175 Med.	180	180 Med.	181	182	183
RBH No. 9002	18.0*	18.0	18.0	68.0	18.0	18.0	68.0	68.0
Ethocel 20 cps Std.	45.0	54.5		66.0			66.0	66.0
Ethocel 20 cps Med.			45.0					
Ethocel 30 cps. Med.					45.0			
Ethocel 10 cps Med.						45.0		
Durez 550	36.5		36.5					
Durez 570		45.0						
Aroplaz 930	3.0	3.0	3.0					
PR 1071				46.5	69.5	69.5	460.0	263.0
Tricresyl Phosphate						3.0		
Ethanol	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5
Toluol	161.0	147.0	161.0	161.0	161.0	161.0	161.0	161.0

* All weights in grams.

TABLE IV

RESULTS OF TESTS

SURFACER	62	179	180	180A	180B	180C	180D	180E	181
Pencil Hardness	3H	4H	4H	2H	3H	4H	3H	3H	4H
Adhesion	Good	Good	Good	Poor	Fair	Fair	Fair	Fair	Good
Flexibility	Fair	Fair	Very Good	Good	Fair	Poor	Fair	Fair	Fair

ETHOCEL LACQUER	62	175	175 Med.	176	180	180 Med.	181	182	183
Pencil Hardness	3H	2H	2H	3H	4H	4H	3H	3H	4H
Adhesion	Good	Fair	Fair	Good	Good	Fair	Good	Good	Very Good
Flexibility	Good	Fair	Poor	Fair	Fair	Fair	Fair	Good	Very Good
Gloss	Poor	Fair	Fair	Good	Good	Good	Good	Good	Good

CONCLUSIONS

The grey sanding surfacer shows great possibility in the commercial field because it exhibits properties that are second to no surfacer on the market today. Surfacer No. 179 is the formulation that is recommended where a surfacer of good hardness, flexibility and adhesion is required.

Ethocel used in an automobile lacquer will not reach the market with the present resins that are available; and in the future, no further work should be done of this problem. The results would indicate that No. 183 was superior to all the other lacquers investigated, but when the film was two months old the oil used to modify resin RR-1071 was completely oxidized and the film lost all of its flexibility.

The Dow Chemical Company of Midland, Michigan, for whom this research was conducted concurs on the above conclusions.

It is recommended that this research conclude the problem of developing an ethocel touch-up lacquer because of the negative results obtained in this and in other investigations.

PART II

A STUDY OF THE PHYSIOLOGICAL EFFECT OF COLOR USING THE MUNSELL COLOR NOTATION

INTRODUCTION

The purpose of this research was to determine the change in shade preferred by a customer if his favorite color were to change due to age. This change is one that has been noticed as a protective coating ages and changes from one shade of a color to an entirely different shade. Knowing the preference of the customer, this change may be made pleasing or displeasing depending upon the formulation of the basic color. This study utilized the Munsell Color Notation (13) that is described in the following pages.

HISTORICAL

THE MUNSELL COLOR SYSTEM

The description and classification of colors were beyond the scope of any language until Mr. Albert H. Munsell utilized the skeleton ideas of his predecessors in originating the color system now bearing his name.

Chevreul, a pioneer in the field of color study, performed some very splendid work on a color system, but it was of very little value to the layman because it was based on the irregularities of various dye and pigment mixtures. The limitations and the complications of such a system are obvious. The reproduction of certain colors by using the same proportions of identical pigments of different batches would very quickly slip into the realms of the impossible.

Helmholtz, a great scientist of his day, who gave considerable attention to the inadequacies of Chevreul's system, stated that color had three dimensions. His theory was lost to mankind, however, because his death prevented its presentation.

Mr. Albert H. Munsell in the late nineties combined his ideas with those set forth by Chevreul and Helmholtz to illustrate the three dimensions of color: HUE, VALUE and CHROMA.

HUE: That property of color which allows you to distinguish between red and green, green and yellow, blue and purple, and all other different basic colors. Hue is designated by the following letters: R for red, YR for yellow-red, Y for yellow, etc. Hue is the first characteristic of color that the eye can detect.

VALUE: Between the two extremes of a pure white, so light that no color may be seen in it, and a pure black, so dark that no color can be seen in it, may be distinguished various degrees of light strength that will range from dark grey (just above black) to light grey (just below white). For example, yellow is usually a light color nearer to white than to black; purple-blue is usually a dark color nearer to black than to white. This variable light strength is referred to as Value. Most yellows are high in value and most purple-blues are low in value, but either can be just the opposite.

Pure white and pure black are at the present time unobtainable. Pure black is designated by the numerical value of 0 and pure white is designated as 10. The blacks that are readily produceable seldom fall below the numerical value of 1 and whites seldom go higher than 9. Practically, pure black is obtainable by lining a box with black velvet and looking into it through a hole in the cover. Pure Magnesium oxide approaches pure white by a value of 9.7 to 9.9.

It is noted that 5 is the middle value between pure white and pure black. Pure grey is found on the neutral axis and is designated as N^4, N^5, N^8, etc., depending upon the value possessed by the particular grey.

If any color is compared with the different greys of the scale, it is easy to distinguish the value of the particular color. The value simply indicates how light or how dark a color is. R^5, Y^5, G^5, and P^5 are all the same value, so one is neither lighter nor darker than the other. (See Fig. I for a graphic illustration of Value.)

CHROMA: Two colors may have the same hue and also the same value, but one is a stronger color than the other. This property of color is called chroma. Chroma measures the degree of strength the color possesses.

Chroma is measured on a line perpendicular to the value axis from /0 at the axis out to /10 representing the strongest Chroma obtainable for the particular hue. For example, a green midway between black and white, five steps out, in Chroma is represented by G5/5.

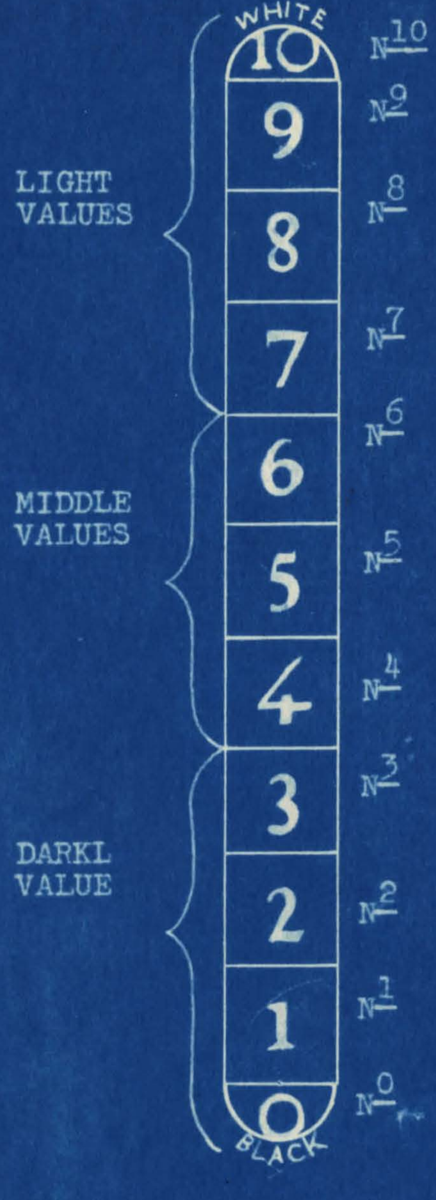
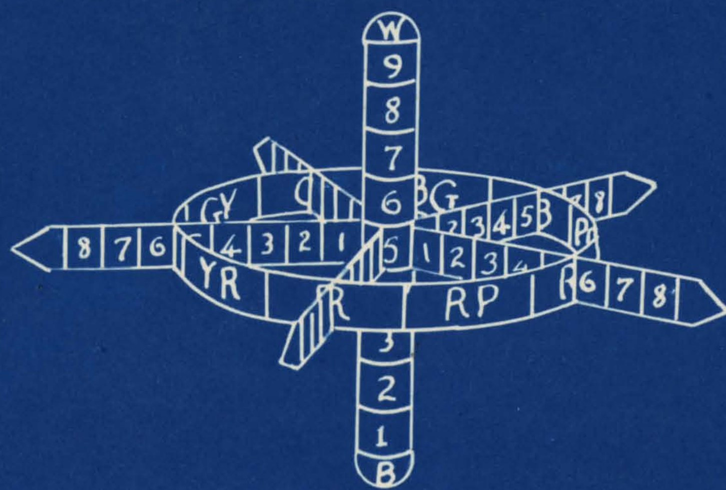


FIGURE I

SCALE OF MUNSELL VALUES ON THE NEUTRAL AXIS

FIGURE II



Hue, Value and Chroma Diagram
(Their Relationships to Each Other)

A hue reaches its maximum chroma at only one value, and all hues do not reach their maximum chroma at the same level of value. The following hues were investigated as a partial fulfillment of this study: red, yellow and red-green.

TEST PROCEDURE

The Munsell color chips were arranged as shown in Tables IV, V and VI on the "Individual Analysis Sheet Showing the Munsell Color Card Arrangement." The center chips of Board II on the above charts were the standards in each color set. This standard color was shown to the observer and the observer was asked to assume that this color was one that he would like to have but that he could not obtain. Following this assumption, the observer was given a choice of the corresponding color on Board I or III, that is 2.5 - 6/6 and 7.5 - 6/6. This determined the observer's hue preference.

Second, from the board containing the observer's hue preference, the observer was again asked to choose between two colors representing a difference in value, but of the same hue and chroma as the first selection. Example: Green 5G 6/4 was the green standard. The observer chose between 2.5G 6/4 and 7.5G 6/4. Suppose the observer had chosen 2.5G 6/4. Then, his next choice was between 2.5G 7/4 and 2.5G 5/4.

Third, the observer chose a color of the same hue and value as his second choice, but of different chroma.

Fourth, the observer was allowed another choice in value. Suppose that in the example above, the observer's choice was 2.5G 7/4. He was then given a choice between 2.5G 7/6 and 2.5G 7/2. If he then chose 2.5G 7/2, he was given a choice between 2.5G 7/2 and 2.5G 6/2, allowing him to reverse a former tendency.

Many observers did reverse themselves in the fourth choice; and when these observers were questioned, it was disclosed that the original choice in value was too extreme to suit them. This means that in the example, the observer did not like 2.5G 5/4 or 2.5G 7/4, but that 2.5G 7/4 was the more pleasing color and more in the range that he would accept. Final selection of 2.5G 6/2 meant that he liked the neutral value better than 2.5G 7/2.

A fifth choice was allowed on the red and part of the yellow-reds and greens. This choice was made in a hue between the first hue chosen and the standard hue. In the example above, if the observer's fourth choice had been 2.5G 6/2, then he would have been allowed to choose between 2.5G 6/2 and 5.G 6/2. Selection of 5G 6/2 would indicate that the 2.5 hue was more acceptable than the 7.5 hue, but that 2.5G was too extreme or that the neutral 5G was more desirable.

All colors were covered during the test except those which were being shown to the observer. In the first choice, cards 2.5G 6/4, 5G 6/4, 7.5G 6/4 were open for the selection of either 2.5G 6/4 or 7.5G 6/4. Then, these colors were covered, and 7/4 and 5/4 were uncovered on the board of first selection, etc. The observers were instructed to choose on the merit of the color rather than to try to match with the standard. Observers were also instructed to refrain from choosing the color merely because it would look pretty on some particular object.

TABLE I

INDIVIDUAL ANALYSIS SHEET SHOWING MUNSELL YELLOW-RED CHIP ARRANGEMENT

NAME

LAST FIRST AGE SEX YEAR MAJOR

CHROMA 8

VALUE 7

I			II			III		
7	8	9	7	8	9	7	8	9
7/8	7/6	7/4	7/8	7/6	7/4	7/8	7/6	7/4
4	5	6	4	5	6	4	5	6
6/8	6/6	6/4	6/8	6/6	6/4	6/8	6/6	6/4
1	2	3	1	2	3	1	2	3
5/8	5/6	5/4	5/8	5/6	5/4	5/8	5/6	5.4

HUE 2.5   5   7.5

TABLE II

INDIVIDUAL ANALYSIS SHEET SHOWING MUNSELL RED CHIP ARRANGEMENT

NAME ____

LAST FIRST AGE SEX YEAR MAJOR

CHROMA 10

VALUE 5

	I			II			III		
	7	8	9	7	8	9	7	8	9
	5/10	5/8	5/6	5/10	5/8	5/6	5/10	5/8	5/6
	4	5	6	4	5	6	4	5	6
	4/10	4/8	4/6	5/10	5/8	5/6	5/10	5/8	5/6
	1	2	3	1	2	3	1	2	3
	3/10	3/8	3/6	3/10	3/8	3/6	3/10	3/8	3/6
HUE	2.5			5			7.5		

Table III

INDIVIDUAL ANALYSIS SHEET SHOWING MUNSELL GREEN CHIP ARRANGEMENT

NAME ______________________________

LAST FIRST AGE SEX YEAR MAJOR

CHROMA 6 ↓

VALUE 7 →

I			II			III		
7	8	9	7	8	9	7	8	9
7/6	7/4	7/2	7/6	7/4	7/2	7/6	7/4	7/2
4	5	6	4	5	6	4	5	6
6/6	6/4	6/2	6/6	6/4	6/2	6/6	6/4	6/2
1	2	3	1	2	3	1	2	3
5/6	5/4	5/2	5/6	5/4	5/2	5/6	5/4	5/2

HUE 2.5 5 7.5

TABLE IV

CONVERTING HUNTER REFLECTOMETER VALUES TO THE BUREAU OF STANDARDS COLOR VALUES

STANDARD 2.5 GREEN

	6/4	5/2	6/2	7/2	5/4	7/4	5/6	6/6	7/6
Blue Settings (Hunter)	.253	.184	.272	.373	.158	.344	.144	.212	.318
Amber Settings (Hunter)	.262	.188	.280	.384	.171	.362	.158	.230	.348
Green Settings (Hunter)	.313	.211	.310	.414	.210	.423	.208	.301	.433
B = .803 x Blue	.2035	.148	.219	.300	.127	.2765	.1158	.1705	.256
A = .816 x Amber	.214	.1535	.2285	.313	.1395	.296	.129	.1875	.284
Y = G = .817 x Green	.255	.172	.253	.338	.1715	.345	.170	.2455	.354
L = Y 1/2 = G 1/2	.505	.415	.504	.583	.416	.588	.411	.496	.596
L = K_1 (Y 1/2)		-9.0	-.1	+7.8	-8.9	+8.3	-9.4	-1.9	+9.1
A-G (Note Sign)	-.041	-.0185	-.0245	-.0250	-.0320	-.050	-.041	-.0580	-.070
G-B (Note Sign)	+.0545	+.024	+.034	+.038	+.0445	+.0685	+.0542	+.0750	+.098
.4 (G-B)	.0218	.0096	.0136	.0152	.01785	.0274	.02165	.030	.0392
Dem. = B + A + 2G	.9275	.6455	.953	1.289	.6095	1.2615	.5848	.8490	1.248
α = A-G/Dem.	-.04425	.02865	.0257	.0194	.0525	.0396	.070	.0683	.0561
β = .4 (G-B) Dem.	+.0235	.01487	.01297	.0118	.0292	.0217	.037	.0353	.0314
$\sqrt{\alpha^2 + \beta^2}$	.0501	.0323	.0288	.0227	.0600	.0452	.0792	.0770	.0650
$\Delta(\sqrt{\alpha^2 + \beta^2})$		-.0178	-.0213	-.0274	+.0099	-.0049	+.0291	+.0269	+.0149
700 Y 1/4	.711 498	.644 451	.709 496	.763 534	.644 451	.767 537	.642 450	.704 493	.772 540
ΔS = 700 Y 1/4 $\Delta(\sqrt{\alpha^2 + \beta^2})$		-8.03	-10.6	-14.5	+4.46	-2.63	+13.1	+13.1	+8.05
β/α	.532	.519	.504	.607	.557	.548	.529	.516	.56
ϕ = Angle whose tangent is β/α	28 152	27.4 152.6	26.75 153.25	31.25 148.75	29.8 150.2	28.7 151.3	27.88 152.12	27.28 152.72	29.25 150.75
$\Delta\phi$		+.6	+1.25	-3.25	-1.8	-.7	+.12	+.72	-1.25
12.2 Y 1/4	8.67	7.87	8.66	9.32	7.87	9.33	7.83	8.59	9.42
12.2 Y 1/4 $\sqrt{\alpha^2 + B^2}$		+4.72	+10.82	-30.3	-14.15	-6.53	+.94	+6.18	-11.77
H = 12.2 Y 1/4 $\sqrt{\alpha^2 + B^2}$ $\Delta\phi$		+.1475	+.312	-.687	-.85	-.295	+.0745	+.476	-.765

45

TABLE V

MEASUREMENTS OF HUE, VALUE AND CHROMA DIFFERENCE ESTIMATES BETWEEN

MUNSELL COLOR CHIPS FOR 5 GREEN

STANDARD

	6/4	5/2	6/2	7/2	5/4	7/4	5/6	6/6	7/6
Blue Settings (Hunter)	.264	.185	.283	.384	.160	.371	.153	.239	.370
Amber Settings (Hunter)	.238	.172	.265	.363	.142	.336	.129	.199	.319
Green Settings (Hunter)	.297	.195	.299	.404	.182	.409	.180	.277	.414
B = .803 x Blue	.212	.149	.227	.309	.1285	.298	.123	.192	.297
A = .816 X Amber	.194	.1405	.216	.296	.116	.274	.105	.1625	.260
Y = G = .817 x Green	.2425	.1595	.244	.330	.1485	.334	.147	.226	.338
L = Y 1/2 = G 1/2	.492	.398	.494	.574	.384	.578	.382	.474	.5825
L = $K_1 \Delta$ (Y 1/2)		-9.4	+.2	+8.2	-10.8	+8.6	-11.0	-1.8	+9.05
A - G (Note Sign)	-.0485	-.0190	-.028	-.0340	-.0325	-.060	-.042	-.0635	-.078
G - B (Note Sign)	+.0305	+.0105	+.017	+.021	+.020	+.036	+.024	+.034	+.041
.4 (G - B)	.0122	.0042	.0068	.0084	.008	.0144	.0096	.0136	.0164
Dem. = B + A + 2G	.891	.6085	.931	1.265	.5415	1.240	.622	.8065	1.233
α = A - G/Dem.	-.0543	-.0313	-.0301	-.0269	-.06	-.0484	-.0675	-.0775	-.0632
β = .4(G-B)/Dem.	.0137	.00792	.0073	.00665	.0145	.0116	.0154	.0169	.0133
$\sqrt{\alpha^2 + \beta^2}$	.056	.0323	.0309	.0277	.0617	.0498	.0693	.0793	.0646
$\Delta(\sqrt{\alpha^2 + \beta^2})$		-.0237	-.0251	-.0283	+.005	-.0062	+.0133	+.0133	+.0086
700 Y 1/4	.702	.632	.702	.758	.62	.76	.618	.688	.763
	491	442	491	530	434	532	433	482	534
Δ S = 700 Y 1/4 Δ $(\sqrt{\alpha^2+\beta^2})$		-10.48	-12.33	-15.0	+2.170	-3.3	+5.77	+6.43	+4.6
β/α	.252	.253	.2425	.247	.2408	.24	.228	.218	.211
ϕ = Angle whose tangent is B/A	14.15 165.85	14.20 165.80	13.63 166.37	13.9 166.1	13.59 166.46	13.5 166.5	12.85 167.15	12.32 167.68	11.92 168.08
$\Delta\phi$		-.05	+.52	+.25	+.61	+.65	+1.3	+1.83	+2.17
12.2 Y 1/4	8.56	7.72	8.56	9.25	7.57	9.28	7.55	8.4	9.31
12.2 Y 1/4 $\sqrt{\alpha^2 + \beta^2}$	.479	.249	.264	.2565	.467	.463	.523	.667	.602
H = 12.2 Y 1/4 $\sqrt{\beta^2 + \alpha^2}$ $\Delta\phi$		+.01245	+.128	+.0641	+.2845	+.3015	+.68	+1.22	+1.305

TABLE VI

MEASUREMENTS OF HUE, VALUE AND CHROMA DIFFERENCE ESTIMATES

BETWEEN MUNSELL COLOR CHIPS FOR 7.5 GREEN STANDARD

	6/4	5/2	6/2	7/2	5/4	7/4	5/6	6/6	7/6
Blue Settings (Hunter)	.303	.187	.288	.421	.183	.413	.190	.300	.412
Amber Settings (Hunter)	.253	.172	.269	.400	.151	.357	.138	.235	.342
Green Settings (Hunter)	.322	.196	.307	.442	.198	.424	.199	.325	.433
B = .803 x Blue	.2435	.1504	.2315	.339	.147	.332	.153	.241	.331
A = .816 x Amber	.2065	.1405	.2195	.3265	.123	.291	.1125	.1915	.279
Y = G = .817 x Green	.263	.160	.251	.361	.1615	.346	.1625	.265	.354
L = Y 1/2 = G 1/2	.513	.399	.502	.591	.401	.589	.403	.514	.595
L = K_1 Δ(Y 1/2)		-11.4	-01.1	+12.2	-11.2	+07.6	-11.0	+00.1	+08.2
A-G (Note Sign)	-.0565	-.0195	-.0315	-.0345	-.0385	-.055	-.050	-.0735	-.075
G-B (Note Sign)	+.0195	+.0096	+.0195	+.022	+.0145	+.014	+.0095	+.024	+.023
0.4 (G - B)	+.0078	+.00384	+.0078	+.0088	+.0058	+.0056	+.0038	+.0096	+.0092
Dem. = B + A + 2G	.9761	.6109	.9531	1.3675	.5931	1.315	.5905	.9625	1.318
α = A-G/Dem.	-.0579	-.0319	-.0330	-.0252	-.0648	-.0418	-.0847	-.0764	-.0569
β = 0.4 (G-B)/Dem.	+.0080	+.00628	+.00818	+.006425	+.00977	+.00426	+.00643	+.00997	+.006975
$\sqrt{\alpha^2 + \beta^2}$	.0585	.0325	.0340	.026	.0655	.0421	.085	.077	.0573
$\Delta(\sqrt{\alpha^2 + \beta^2})$		-.0260	-.0245	-.0325	+.0070	-.0164	+.0265	+.0185	-.0012
700 Y 1/4	.716	.632	.708	.775	.633	.767	.635	.717	.772
	501	442	496	542	443	537	444	502	540
S = 700 Y 1/4 $\Delta(\sqrt{\alpha^2 + \beta^2})$		-11.5	-12.13	-17.6	+3.1	-8.76	+11.75	+9.3	-.648
	-.1382	-.1972	-.248	-.255	-.1508	-.104	-.076	-.131	-.1206
ϕ = Angle whose tangent is β/α	7.87 172.13	11.17 168.83	13.94 166.06	14.32 165.68	8.58 171.42	5.95 174.05	4.36 175.64	7.47 172.53	6.88 173.12
$\Delta\phi$		-3.30	-6.07	-6.45	-.71	+1.92	+3.51	+.40	-.99
12.2 Y 1/4	8.73	7.7	8.63	9.45	7.72	9.35	7.75	8.74	9.4
12.2 Y 1/4 $\sqrt{\alpha^2 + \beta^2}$	.512	.25	.294	.2455	.505	.394	.658	.673	.538
= 12.2 Y 1/4 $\sqrt{\alpha^2 + \beta^2}$ $\Delta\phi$		-.825	-1.785	-1.585	-.3585	+.757	+2.31	+.2695	-.533

SAMPLE CALCULATIONS

The procedure for converting Hunter Reflectometer readings to Bureau of Standards values is covered in the Bureau of Standards Circular C429 "Photoelectric Tristimulus Colorimetry with Three Filters." (14) The following sample calculation measures the due difference estimate, H^1, the saturation difference estimate S^1, and the lightness difference estimate L^1, between an actual earth sample and two modified earth. Computational short cuts minus scale correction omitted, no calabrated standard used, and factor 0.5 used instead of the actual transmission of neutral filter. $k_1 = 100$, $g = 1.00$.

SPECIMEN	EARTH MIXTURE	MODIFICATION #1	MODIFICATION #2
Blue reading	0.295	0.260	0.370
B=Above times 0.5	.147	.130	.185
Amber reading	.496	.446	.575
A = above times 0.5	.248	.223	.287
Green reading	.428	.386	.508
Y = G = Above x 6.5	.214	.193	.254
L = Y 1/2 = 6 1/2	.453	.439	.504
$\Delta L^1 - K_1 \Delta (Y1/2)$		2.4	+4.1
A-G (Note Sign)	+.034	+.030	+.0335
G-B (Note Sign)	+.0665	+.063	+.069
0.4 (G-B)	+.0266	+.0252	+.0276
Demoninator = B + A + 2G	.8235	.739	.9805
A = (A-G) / dem.	+.0413	+.0406	+.0342
B = 0.4 (G-B) / dem.	+.0323	+.0341	+.0281
$\sqrt{a^2 + B^2}$	.0525	.0528	.0443
$\Delta \sqrt{a^2 + B^2}$		+.0003	-.0082
700 Y 1/4 *		470.	487.
$\Delta S^1 = 700 \times 1/4 \sqrt{L + B^2}$		+0.14	- 3.99
B/a	+.782	+.840	+.822
Δ whose ton is B/a	38.03°	40.03°	39.42°
$\Delta \phi$		+2.00°	+1.39°
12.2 Y 1/4*		8.19	8.48
$12.2\ Y\ 1/4 \sqrt{A^2 + B^2}$ *		0.431	0.411
$\Delta H = 12.2\ Y\ 1/4 \sqrt{A^2 + B^2} - \Delta \phi$		+0.86	+0.57
Color of med. relative to that of actual earth, according to measurement.		Darker Greener Slightly Stronger	Lighter Weaker Slightly Greener

* Ave. for 2 specimens being compared should be entered in those rows marked by asterisk.

EXPLANATION OF TABLES

Tables VII, VIII and IX illustrate the likes and the dislikes of the people tested as to HUE, VALUE and CHROMA.

A. Total test data give the percent of the total number of persons tested who preferred either hue 2.5 or 7.5, value 5,6 or 7 and chroma 4 or 8.

B. If there had not been a second choice as to value, the results would be as shown in B.

C. A certain per cent of the persons tested believed that the difference between 2.5 or 5 and 5 or 7.5 was too great to obtain accurate results. This per cent is shown in C.

D. The men tested indicated a slightly different preference than the women tested. Test D shows the preference for men.

E. This test is similar to B, except that the data represents only male preference.

F. This test is similar to C, except the data represents only male preference.

G. This is a breakdown of female preferences and is similar to Test D.

H. This test is the same as Test E, except that it is restricted to female choices.

I. This is the same as Test F except that it is restricted to female choices.

J. This test shows a numerical breakdown of the final preferences made by the male, female and total male and female.

K. This test shows the relative position of the colors.

TABLE VII

YELLOW RED

A. Total Test Results

	(1) Color Value	(2) Choice of Persons Tested	(3) Ratio of Number Choice to Total Tested	(4) Per cent Desiring Particular Color Value
Hue	2.5	157	157 : 205	76.4
	7.5	48	48 : 205	23.4
				100.0
Value	7	101	101 : 205	49.3
	6	69	69 : 205	33.7
	5	35	35 : 205	17.0
				100.0
Chroma	8	108	108 : 205	52.7
	4	97	97 : 205	47.3
				100.0

B. If Second Choice in Value had not been Allowed

	(1)	(2)	(3)	(4)
Value	7	145	145 : 205	70.7
	5	6-	60 : 205	29.3
				100.0

C. Per cent Believing the Hue was carried to Excess

	(1)	(2)	(3)	(4)
(too intense)	2.5	24	24 : 85	28.2
(too intense)	7.5	12	12 : 85	14.1

TABLE VII
(continued)

D. Breakdown (Male)

	(1)	(2)	(3)	(4)
Hue	2.5	87	87 : 112	77.7
	7.5	25	25 : 112	22.3
				100.0
Value	7	47	47 : 112	42
	6	40	40 : 112	35.7
	5	25	25 : 112	22.3
				100.0
Chroma	8	74	74 : 112	66
	4	38	38 : 112	34
				100.0

E. If Second Choice in Value had not been Allowed

Value	7	70	70 : 112	62.5
	5	42	42 : 112	37.5
				100.0

F. Per cent Believing the Hue Carried to Excess

	2.5			
	2.5	6	6 : 27	22.2
	7.5	3	3 : 27	11.1
				33.3

TABLE VII
(continued)

G. Breakdown (Female)

	(1)	(2)	(3)	(4)
Hue	2.5	70	70 : 93	75.3
	7.5	23	23 : 93	24.7
				100.0
Value	7	54	54 : 93	58.1
	6	29	29 : 93	31.2
	5	10	10 : 93	10.7
				100.0
Chroma	8	34	34 : 93	36.6
	4	59	59 : 93	63.4
				100.0

H. If Second Choice in Value had not been Allowed

Value	7	75	75 : 93	80.7
	5	18	18 : 93	19.3
				100.0

I. Per cent Believing the Hue was Carried to Excess

	2.5	18	18 : 58	31.0
	7.5	9	9 : 58	15.5
				46.5

TABLE VII
(continued)

J. <u>Card</u> <u>Breakdown</u>

	Male	Female	Total
2.5 YR 7/8	24	22	46
2.5 YR 7/4	11	17	28
2.5 YR 6/8	$16_H, 12_L$	$2_H 1_L$	$18_H 13_L$
2.5 YR 6/4	$5_H 1_L$	$16_H 4_L$	$21_H 5_L$
2.5 YR 5/8	7	3	10
2.5 YR 5/4	11	5	16
7.5 YR 7/8	8	4	12
7.5 YR 7/4	4	11	15
7.5 YR 6/8	2_L	1_L	3_L
7.5 YR 6/4	$2_H 2_L$	$3_H 2_L$	$5_H 4_L$
7.5 YR 5/8	5	1	6
7.5 YR 5/4	2	1	3

TABLE VIII

RED

Total Tests	(1)	(2)	(3)	(4)
Hue	2.5 -	96	- 96/134	- 71.6
	7.5 -	38	- 38/134	- 28.4
				100
Value	5 -	37	- 37/134	- 27.6
	4 -	41	- 41/134	- 30.6
	3 -	56	- 56/134	- 41.8
				100
Chroma	10 -	100		74.6
	6 -	34		25.4
				100
If Second Choice in value had not been allowed:				
Value	5 -	64		47.8
	3 -	70		52.2
				100
Percent believing Hue carried to excess:				
Hue	2.5 -	32		23.9
	7.5 -	18		13.42
				47.32
Breakdown - Male				
Hue	2.5 -	40		64.6
	7.5 -	22		35.4
				100
Value	5 -	17		27.4
	4 -	12		19.35
	3 -	33		53.2
				100
Chroma	10 -	47		75.8
	6 -	15		24.2
				100
If second choice in value had not been allowed:				
Value	5 -	23		37.2
	3 -	39		62.8
				100

Table VIII (continued)

Percent believing Hue carried to excess:

Hue	2.5 - 21	33.8
	7.5 - 4	6.44
		40.24

Breakdown - Female

Hue	2.5 - 56	77.8
	7.5 - 16	22.2
		100
Value	5 - 20	27.8
	4 - 29	40.3
	3 - 23	31.9
		100
Chroma	10 - 53	73.5
	6 - 19	26.5
		100

If second choice had not been allowed:

Value	5 - 41	57.0
	3 - 21	43.0
		100

Percent believing Hue carried to excess:

Hue	2.5 - 24	33.4
	7.5 - 4	5.56
		38.96%

Card Breakdown:

	Male	Female	Total
2.5R 5/10	5	9	14
2.5R 5/6	4	5	9
2.5R 4/10	$4_H, 2_L$	$16_H, 5_L$	$20_H, 7_L$
2.5R 4/6	1_L	$1_H, 1_L$	$1_H, 2_L$
2.5R 3/10	16	17	33
2.5R 3/6	8	2	10
7.5R 5/10	7	1	8
7.5R 5/6	1	5	6
7.5R 4/10	$2_H, 3_L$	1_L	$2_H, 4_L$
7.5R 4/6	0	$4_H, 1_L$	$4_H, 1_L$
7.5R 3/10	8	4	12
7.5R 3/6	1	0	1

TABLE IX

GREEN

Total Tests	(1)	(3)	(4)
Hue	2.5 -	59/138	= 42.7%
	7.5 -	79/138	= 57.3
			100.0
Value	5 -	39/138	= 28.3
	6 -	52/138	= 37.7
	7 -	47/138	= 34.0
			100.0
Chroma	2 -	92/138	= 66.7
	6 -	46/138	= 33.3
			100.0

If second choice in value had not been allowed:

Value	7 -	79/138	= 57.3
	5 -	59/138	= 42.7
			100.0

Breakdown - Male

Hue	2.5 -	41/90	= 45.6
	7.5 -	49/90	= 54.4
			100.0
Value	5 -	28/90	= 31.1
	6 -	34/90	= 37.8
	7 -	28/90	= 31.1
			100.0
Chroma	2 -	70/90	= 77.8
	6 -	20/90	= 22.2
			100.0

Breakdown - Female

Hue	2.5 -	18/48	= 37.5
	7.5 -	30/48	= 62.5
			100.0
Value	7 -	19/48	= 39.6
	6 -	18/48	= 37.5
	5 -	11/48	= 22.9
			100.0
Chroma	6 -	26/48	= 54.2
	2 -	22/48	= 45.8
			100.0

TABLE IX (continued)

<u>If second choice in value had not been allowed:</u>

	(1)	(3)	(4)
Value	7 -	29/48	= 60.4
	5 -	19/48	= 39.6
			100.0

<u>Percent believing Hue carried to excess:</u>

Hue	2.5 -	9/48	= 18.75
	7.5 -	19/48	= 39.6
			58.35

<u>Card Breakdown:</u>

	Male	Female	Total
2.50 7/6	5	7	12
2.50 7/4	11	3	14
2.50 6/6	1_H	2_L	$1_H, 2_L$
2.50 6/2	$5_H, 3_L$	3_H	$8_H, 3_L$
2.50 5/6	4	1	5
2.50 5/2	12	2	14
7.50 7/6	4	7	11
7.50 7/2	8	2	10
7.50 6/6	$2_H, 1_L$	$3_H, 2_L$	$5_H, 3_L$
7.50 6/2	$14_H, 8_L$	$4_H\ 4_L$	$18_H, 12_L$
7.50 5/6	3	4	7
7.50 5/2	9	4	13

OBSERVATION

Some observers reversed themselves in value on choice #4 from their selection on choice #2. This was because choice #2 was considered too extreme. The same was true of observers reversing the selection of hue on choice #5.

All observers tend to choose a color that will look best on some particular object. Men think of paint, and women, of clothes.

Almost everyone claiming color blindness could distinguish a difference in any two colors, therefore results of tests were not materially changed.

From the findings of one or two colors it is impossible to forecast the results for a third color.

HUE: In all cases the bluer hue was preferred, but to a greater extent by women, especially in the case of green. In the Munsell system, the closer the color approaches blue, the greater the tendency to consider the bluer hue choice excessive.

VALUE: In all cases women prefer their colors to be brighter than do men. Men prefer dark reds, medium greens and light yellow reds.

CHROMA: Men like greens to be quite grey, but they like yellow reds to be well-saturated. Women are just the opposite. Both men and women, however, want reds of strong chroma.

Table X

COLOR CHANGE PREFERENCE

Standard Color	Male Preference Hue	Value	Chroma	Female Preference Hue	Value	Chroma
5 Red 4/8	Bluer	Dark	Strong	Bluer	Medium	Strong
5 G 6/4	Bluer	Medium	Weak	Bluer	Light	*Strong
5 YR 6/6	Redder	Light	Strong	Redder	Light	Weak

*Fairly Strong

PROJECTION

Further study of additional dark colors and tints is necessary to determine color preference. These findings will be applied to representative color cards, which will then be tested as proof of the theory. Part II of this thesis is concerned with only a portion of this study; and on the completion of the study, it will be incorporated into the final results.

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VITA

Thaddeus Andrew Peake, Jr. was born in Louisville, Kentucky on October 21, 1919, son of Thaddeus Andrew and Mary Elizabeth Peake. He received his primary education at Stephen Foster School and at Shawnee School. His high school education was completed at Louisville Male High School and his college work was done at the Speed Scientific School of the University of Louisville. He received his Bachelor of Chemical Engineering Degree in June of 1941. He at once entered the Graduate School in pursuit of his Master of Arts Degree in Chemical Engineering; but when war was declared on Germany and Japan December 7, 1941, he enlisted in the United States Naval Academy for midshipman training.

On September 8, 1942, he received his commission as Ensign, Engineer (Volunteer) General, U.S.N.R. The following Navy Courses were completed by him: (1) Naval Mine Warfare Course, Yorktown, Virginia. (2) Mine Disposal Course, Navy Yard, Washington, D.C. (3) Deep Sea Diving Course, Navy Yard, Washington, D.C. (4) High Voltage X-Ray Course, Naval Powder Factory, Indiana Head, Maryland. On completion of the above courses, he was a qualified Mine Disposal Officer, Second Class Deep Sea Diver and Operator of High Voltage X-Ray Units for Explosive Investigation.

Mr. Peake was married to Martha Jane Schott of Louisville, Kentucky April 8, 1943.

Immediately, upon completing the above courses, he was ordered to the Explosive Investigation Laboratory, Port Townsend, Washington as Officer-in-Charge. After one and one-half year's duty at Port Townsend, he was ordered to the Mobile Explosive Investigation Unit No. 4 at Pearl Harbor, T.H. While he was attached to the Mobile Explosive Investigation Unit #4, he took active part in the Mine Disposal Operations of Okinawa and also in the initial phases of the occupation of Japan. While he was in Japan, he was attached to the Naval Technical Mission to Japan in charge of Mine Disposal Intelligence. On February 25, 1946, he was placed on inactive Naval Duty with the rank of Lieutenant, which title he received January 11, 1945.

Mr. Peake reentered the Graduate School immediately to complete his Master of Arts Degree in Chemical Engineering at the University of Louisville.